To: Recent Dry Mill Ethanol Pathway Applicants

From: Staff

Date: January 08, 2014

Subject: ARB staff comments on recent dry mill ethanol LCFS pathway applications involving multiple distillers grains dryness levels

Feedstock and Fuel: Corn or sorghum grain and ethanol

Memorandum

Dear Applicant:

You are receiving this because you currently have a dry mill ethanol-process LCFS pathway application before staff for consideration. That application contains two or more separate pathways based on distillers grains with solubles (DGS) dryness levels. Applicants have used different methods to estimate drying energy differences across DGS-dryness-based pathways, and to calculate pathway CIs based on those differences. Staff has reviewed these varying approaches. Because drying systems and processing parameters can vary widely from one plant to the next, we cannot prescribe a single approach that all applicants must use. Applicants will therefore have to propose a specific approach that best reflects conditions in their plants.

Some applicants have set the drying energy equal to the CA-GREET default drying energy value while others have used dryer capacity ratings. Staff finds that these values are not always warranted. Before the CA-GREET default drying energy of 9,900 Btu/gal (lower heating value basis[1]) can be considered a reasonable approximation, specific process conditions should be determined. Below is an example of potential process conditions that may result in 9,900 Btu/gal being used to account for dryer energy use if sensible heat effects are ignored[2] and 91%[3] efficiency is accurate.

- The wet cake must contain approximately 65 percent water
- The syrup (solubles) must contain approximately 65 percent water
- The dry DGS must contain approximately 10 percent water

---

[1] Throughout this memorandum the energy required to dry the DGS is assumed to be on a lower heating value basis due to most plants supplying thermal energy by combustion, and the latent heat of vaporization of water produced during the combustion process is not being utilized. 9,900 Btu/gal requires approximately 11,133 Btu/gal of natural gas at minimum.

[2] Note that sensible heat effects and non-linear drying kinetics (for varying DGS dryness levels) are likely and must be considered in a full drying energy analysis. Plant-specific empirical data that is updated over time is the most accurate method for determining the energy required to dry DGS to an average or specific dryness level.

[3] This efficiency is required if 9,900 Btu/gal is the dryer energy required based upon the stated parameters. The mass of DGS produced in this calculation is based upon CA GREET 1.8 B DGS bone-dry yield of 5.34 lb/gal and 2.72 gal/bu ethanol yield (a parameter used to determine the DGS yield).

- The drying process must be approximately 91 percent efficient

If these or other related conditions are not achieved on average, the 9,900 Btu/gal value is not an accurate estimate of actual drying energy. If actual drying energy is less than 9,900 Btu/gal, use of this value will produce an overestimate of the energy savings associated with the 100 percent wet and 100 percent modified DGS pathways. Dryer capacity ratings are likely to produce similar overestimates because dryers are not always run at full capacity.

For the following reasons, 9,900 Btu/gal or dryer capacity ratings that are greater than 9,900 Btu/gal may be an overestimate of actual drying energy:

1. The CA GREET 1.8b default dryer energy use value of 9,900 Btu/gal was based upon information provided by a consultant to the ARB for the purpose of converting the Argonne GREET model to a California-specific version [1]. The information the consultant provided was based on a source that reported a 1998 average dry mill plant thermal energy consumption of 36,000 Btu/gal, of which 27.5 percent of that energy, according to this source, was used for drying DGS [2]. Although the 9,900 Btu/gal figure does not appear in this source, 27.5 percent of 36,000 is 9,900 Btu/gal. The total thermal energy used by many ethanol plants has decreased since 1998 [3, 4, 5]. Some decreases in individual plant thermal energy use may be due to reduced DGS dryer energy consumption.
2. Dryer energy use can be reduced by improved dryer efficiency or by simply drying DGS to a higher moisture content. One reference suggests that rotary dryers are usually controlled to provide a product in the range of 10-13 percent[4] moisture content [6]. Moisture contents greater than 13 percent may be permissible in some feed markets without causing microbial spoilage or poor flowability caused by particle-to-particle interactions. Another way dryer energy use may be reduced is by reducing the water content of the wet cake or condensed distillers solubles (syrup). Dale and Tyner state that the solids concentration of thin stillage, after passing through multiple effect evaporators and becoming condensed distillers solubles (syrup), can be between 30-60 percent solids [2].
3. The efficiency of decanter centrifuges can be improved through enzymatic dewatering of the whole stillage [7, 8]. There may be other process improvements that allow for greater solids separation in existing or future centrifuge design. A study in a peer reviewed publication reported running tests on wet distillers grains with moisture contents between 53-54 percent (wet basis), which is an11-12 percent lower water content than what is assumed in the default dryer energy of 9,900 Btu/gal [13]. The study that reported the lower water content wet distillers grains was investigating the physical and chemical properties of wet grains obtained from an upper Midwest ethanol plant that was using yellow dent corn.

[4] Staff notes that the energy required to remove the water as the drying progresses beyond any free water remaining (approximately 50% water) is likely non-linear in energy consumption.

4. Distillers grains and solubles material properties have been of interest to ethanol producers and to the animal feed market for many years. Many studies have likely been conducted to better understand and improve the flowability of distillers grains and solubles. Some studies have been published in peer-reviewed journals. Other studies are likely trade-secret process optimization benefits to individual dry mill ethanol plants or companies. Some of the publicly available studies have investigated flowability of DGS under various solubles concentrations, drying temperatures, and the comparative differences associated with reduced fat DGS [14, 15, 16]. The process efficiency of dry mill ethanol plants is improving [5]. Certainly, the mentioned public papers combined with trade secret information have likely improved the evaporator and dryer operations, and DGS quality. These studies and obvious approaches to optimizing processing requires staff to more closely investigate default values or use of capacity ratings for estimating 100 percent wet or modified DGS co-produced ethanol.

5. According to a memorandum provided by GreenShift Corporation to the ARB, “COES I reduces the energy use in the ethanol plant dryers by about 3,700 Btu/ethanol gallon…” [9]. The memorandum GreenShift provided is included in the appendix of the, “California Modified GREET Pathway for the Production of Biodiesel from Corn Oil at Dry Mill Ethanol Plants” and references the material being presented to the US EPA at the Public Hearing on the federal Renewable Fuel Standard Program (“RFS2”) held in Washington DC on June 9, 2009 [9,17,18]. In 2007, GreenShift Corporation’s Chairman and CEO Kevin Kreisler was quoted as saying, “A 100 MMgy ethanol facility will save about $1 million per year in dryer costs.” . . . “and ethanol plants that participate in extraction and host co-located biodiesel production will receive more than $8 million per year (for a 100 MMgy ethanol producer) in additional earnings for no investment” [10]. A presentation obtained from GreenShift Corporation’s website states that using method 1 or method 2 corn oil extraction systems can save approximately 3,500 Btu/gal or 5,500 Btu/gal of ethanol produced, respectively [11]. GreenShift’s current website states, “GreenShift designed its technologies to extract oil in a way that decreases the ethanol facility’s utility costs” and also has a more informal statement at the top of the webpage, “11% less energy in (*input*) per gallon of ethanol produced and 29% less greenhouse gas emissions” [12].

6. There are many possible energy and yield improvements for dry mill ethanol plants. Some of these current and future improvements have been reviewed in the publication, “2012 Corn Ethanol: Emerging Plant Energy and Environmental Technologies” [5]. These technology improvements make it necessary for staff to question energy use based upon equipment ratings or assumed default calculations.

Conclusion

Given the significant plant-to-plant variation in ethanol and DGS operations, staff is not in a position to prescribe specific approaches to determining drying energy, or calculating dryness-based CIs. Based on the information presented in this memo, however, we are asking that the DGS drying energy (thermal and electrical) value that applicants use in their CI calculations be based on plant-specific operational information. We also ask that the information that was used to determine the drying energy be described in detail in the life cycle analysis (LCA) report included in the application.

The simplest and most straightforward operational information on which a drying energy value can be based is validated and verifiable thermal and electrical energy consumption data. This can come from meters or from a plant's automated data-logging system. If available plant energy consumption data can be used to definitively establish the difference in thermal and electrical energy consumption between periods when drying is and is not occurring, no further plant information would be necessary.

If validated and verifiable thermal energy consumption data sufficient to establish dryer energy usage is not available, the applicant must propose an approach to estimating dryer energy usage based on plant-specific information that is available. Although we cannot prescribe one or more acceptable approaches, we ask that the approach the applicant proposes take into consideration the factors discussed in this memorandum, as well as any additional relevant factors not discussed in this memorandum. At a minimum, therefore, a dryness energy estimation approach must take into consideration

- initial wet cake water content,
- final DGS (or DG, if syrup is sold separately) water content,
- initial thin stillage (solubles) water content,
- final solubles (syrup) water content,
- mass of corn oil extracted,
- use of enhanced stillage dewatering (enzymatic or other) , and
- dryer efficiency[5].

All data and information used to develop an approach to drying energy estimation must be provided in the LCA report.

Applicants who conclude that the plant-specific data and information necessary to determine drying energy is not readily available, may opt, instead, to apply for a single CI over all DGS dryness levels, so long as that CI is based on a two-year energy consumption record (or prospective data for new plants with prospective applications),

[5] The dryer efficiency must consider psychometrics if applicable and other factors specific to the dryer and process

and will allow the applicant to attest to the validity of the resultant CI both for present and foreseeable future plant operations[6].

One condition that must be met for the drying energy value used is that it must allow the plant's annual mass and energy balances to approximately close (reconcile with actual annual energy consumption data). Applicants must demonstrate in their LCA reports that the mass and energy balances approximately close and explain any discrepancy that prevents complete closure.

Once drying energy has been determined, use that value to calculate DGS-dryness-based CIs. Those calculations must

- be done on a dry-matter basis, and
- properly account for extracted corn oil and syrup on a dry matter basis. Syrup and corn oil must be allocated proportionally (on a dry-matter basis) to all DGS dryness categories when CIs are calculated for the co-product credit.

When the CIs are certified, the plant must allocate ethanol gallons produced to DGS-dryness categories after converting all DGS masses to a dry-matter basis.

Please contact the staff person responsible for your application if you have questions regarding this memorandum. If you would like to speak with the manager of the Fuels Evaluation Section, please contact Wes Ingram:

Email: wingram@arb.ca.gov

Office: 916-322-3984

References

1. Staff-consultant email communication. April 1, 2011.
2. Dale, R. T., & Tyner, W. E. (2006, April). Economic and Technical Analysis of Ethanol Dry Milling: Model Description. Staff Paper #06-04. Web: http://ageconsearch.umn.edu/handle/28674
3. Mueller, S. (2010, September). 2008 National Dry Mill Corn Ethanol Survey. Biotechnology Letters, pp. Volume 32, Issue 9, pp 1261-1264. Web: http://link.springer.com/article/10.1007%2Fs10529-010-0296-7#
4. Mueller, S. (2010, May). Detailed Report: 2008 National Dry Mill Corn Ethanol Survey. University of Illinois at Chicago, College of Engineering. Web: http://www.ethanol.org/pdf/contentmgmt/Ethanol_production_efficiency_U_of_IL_spring_2010.pdf
5. Mueller, S. & Kwik, J. (2013, April). 2012 Corn Ethanol: Emerging Plant Energy and Environmental Technologies. University of Illinois at Chicago, College of

[6] Title 17, CCR, § 95486(f)(3)(C)12

Engineering. Web:
http://www.erc.uic.edu/PDF/mueller/2012_corn_ethanol_draft4_10_2013.pdf

6. Kingsly, A. R. P., Ileleji, K. E., Clementson, C. L., Garcia, A., Maier, D. E., Stroshine, R. L., & Radcliff, S. (2010). The effect of process variables during drying on the physical and chemical characteristics of corn dried distillers grains with solubles (DDGS)–Plant scale experiments. *Bioresource technology*, *101*(1), 193-199. http://dx.doi.org/10.1016/j.biortech.2009.07.070. (http://www.sciencedirect.com/science/article/pii/S0960852409009602)
7. Henriques, A. B., Johnston, D. B., McAloon, A. J., Dudukovic, M. P. Research: Reduction in energy usage during dry grind ethanol production by enhanced enzymatic dewatering of whole stillage: Plant trial, process model, and economic analysis (2011). Industrial Biotechnology 7(4), pp. 288-297. http://www.scopus.com/inward/record.url?eid=2-s2.0-80052043407&partnerID=40&md5=0ee9b0eedd0c550404f1dddeb906925
8. Henriques, A. B., Johnston, D.B., Al-Dahhan, M. Enhancing water removal from whole stillage by enzyme addition during fermentation (2008). Cereal Chemistry 85 (5) pp. 685-688. http://www.scopus.com/inward/record.url?eid=2-s2.0 53049102170&partnerID=40&md5=f5c6e4865d919cf2f49c555cb4b437b2
9. California Air Resources Board (2010, December). California Modified GREET Pathway for the Production of Biodiesel from Corn Oil at Dry Mill Ethanol Plants. http://www.arb.ca.gov/fuels/lcfs/2a2b/internal/121410lcfs-cornoil-bd-rpt.pdf
10. Watkins, Catharine. Two Fuels from One Kernel. Obtained from GreenShift's website on December 31, 2013: http://www.greenshift.com/wp-content/uploads/2013/03/EPM_One_Kernel_Two_Fuels.pdf
11. GreenShift Corporation. (2009). Backend Fractionation: The Solution is in Solution. Obtained from GreenShift Corporation's website on December 31, 2013: http://www.greenshift.com/wp-content/uploads/2013/03/backend_fractionation.pdf
12. GreenShift Corporation's website, Corn Oil Extraction, Process Description. Obtained from GreenShift Corporation's website on December 31, 2013: http://www.greenshift.com/corn-oil-extraction/process-description/
13. Rosentrater, K. A., & Lehman, R. M. (2008). Physical and chemical properties of corn distillers wet grains. *Applied engineering in agriculture*, *24*(1), 57-62. Link: http://handle.nal.usda.gov/10113/12878
14. Bhadra, R., Rosentrater, K. A., Muthukumarappan, K., & Kannadhason, S. (2011). Drying characteristics of distillers wet grains under varying condensed distillers solubles and drying temperature levels. *Applied Engineering in Agriculture*, *27*(5), 777. Link: http://lib.dr.iastate.edu/abe_eng_pubs/81/
15. Bhadra, R., Muthukumarappan, K., & Rosentrater, K. A. (2012). Effects of CDS and drying temperature levels on the flowability behavior of DDGS. *Drying Technology*, *30*(5), 542-558. Link: http://www.tandfonline.com/doi/abs/10.1080/07373937.2011.649510

16. Ganesan, V., Rosentrater, K. A., & Muthukumarappan, K. (2009). Physical and flow properties of regular and reduced fat distillers dried grains with solubles (DDGS). *Food and Bioprocess Technology*, *2*(2), 156-166. Link: http://link.springer.com/article/10.1007/s11947-007-0026-x#

17. GreenShift Corporation Comments Submitted to US EPA, June 9, 2010. http://federal.eregulations.us/rulemaking/document/EPA-HQ-OAR-2005-0161-3205

18. GreenShift Corporation Comments Submitted to US EPA, June 16, 2010. http://federal.eregulations.us/rulemaking/document/EPA-HQ-OAR-2005-0161-3212